

AD-A115 554 SMITHS INDUSTRIES AEROSPACE AND DEFENSE SYSTEMS INC --ETC F/6 14/2
RELIABILITY AND MAINTAINABILITY IMPROVEMENT PROGRAM FOR THE AV---ETC(U)
MAY 82 M D CARMICHAEL N00019-77-A-0350
UNCLASSIFIED SI-1010-VOL-3 NADC-78080-60-VOL-3 NL

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PRELIMINARY

FINAL ENGINEERING REPORT
FOR
SIGNAL DATA CONVERTER (SDC)
CV-3600/AVQ-30-(V)

CDRL SEQUENCE A003

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Prepared For
Naval Air Systems Command
Washington, D.C.

Issue Date: 28 May 1982 Contract Number: N00019-77-A-0350-WW04, WW07

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Report NADC-78080-60 Volume 3

Reliability and Maintainability Improvement Program
for the AV-8A/TAV-8A Harrier Head-Up Display Set,
Development of the Signal Data Converter, CV-3600/AVQ-30(V)

Smiths Industries Aerospace and Defense Systems Inc.
Clearwater Division
Clearwater, Florida

Final Report

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Prepared for
Naval Air Systems Command(AIR-53352D)
Washington, D.C. 20060



1. Project No.	
2. Report No.	
3. Date	
4. Title	
5. Author	
6. Distributor	
7. Availability Codes	
8. All other	
9. Special	
10. Other	

Pist. *A*

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NADC-78080-60 Volume 3	2. GOVT ACCESSION NO. AD-A175554	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) RELIABILITY AND MAINTAINABILITY IMPROVEMENT PROGRAM FOR THE AV-8A HARRIER HEAD-UP DISPLAY SET, SIGNAL DATA CONVERTER, CV-3600/AVQ-30(V)		5. TYPE OF REPORT & PERIOD COVERED Final Engineering Report 1978 - 1981
7. AUTHOR(s) M.D. Carmichael		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS (813) 531-7781 Smiths Industries Aerospace & Defense Systems Inc. P.O. Box 5389, St. Petersburg/Clearwater Airport Clearwater, Florida 33518 (FSCM 35012)		8. CONTRACT OR GRANT NUMBER(s) N00019-77-A-0350-WW07 *
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Air Development Center (Code 6022) Warminster, PA 18974		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS S.O.W. A533C-01
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Naval Air Systems Command (AIR-53352D) Department of the Navy Washington, D.C. 20361		12. REPORT DATE 28 May 1982
		13. NUMBER OF PAGES 14
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES *This report (Volume 3) covers the SDC portion of the work done under contract, previously N00019-77-A-0350-WW04. Other reports, (Volume 1 and Volume 2), cover the DDI and DSC portions respectively of other tasks.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) (U) Head-Up Display (U) V/STOL Aircraft (U) Computer		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The circuitry driving the head-up display in the AV-8A aircraft, called the Waveform Generator, was revised and updated to improve reliability. The new unit, called the Signal Data Converter, provides greater capability, built-in test features, phosphor protection circuits, reduced size and weight, and greater adaptability to changed input or output requirements.		

ABSTRACT

This final report summarizes the development and design features of the Signal Data Converter, CV-3600/AVQ-30(V), a weapons replaceable assembly (WRA) in the Digital Data Display Set (DDDS), part of the AV-8A/TAV-8A Head-Up Display (HUD) aircraft avionics. Reliability and Maintainability improvements in the HUD system will result by virtue of the following features of the SDC:

- a. All circuitry is digital wherever possible.
- b. Highest reliability components used, with Large Scale Integration wherever possible.
- c. Built-in-test circuits with indicators.
- d. Use of multiwire or multilayer boards.
- e. Improved heat dissipation design.
- f. Extensive environmental testing.

Five SDC units have been built and tested, including flight tests with good results. Recommendations have been made to retain the SDC's at the contractor's facility when not in flight test for further system tests and modifications as required by the Navy.

1.0 BACKGROUND

- 1.1 The Waveform Generator (WFG) Part No. 202 SUE/5, has been used as a part of the HUD system in the AV-8A and TAV-8A aircraft for over ten years, and has become increasingly unreliable and difficult to maintain. The HUD Set Mean Time Between Failure (MTBF) is 45.8 hours and is steadily degrading.

The WFG is the major cause of the poor reliability of the AV-8A HUD Set. The MTBF of the WFG is 75.0 hours. All Shop Replaceable Assemblies (SRA's) of the WFG are sent to SIADS Inc. for depot repair because the WFG was originally designed for use in the Royal Air Force Harrier and hence, was not compatible with Marine Corps and Navy fleet maintenance. Parts have become increasingly expensive and difficult to maintain because of obsolescence. Maintenance costs for the WFG are excessive.

Previous studies conducted by ARINC and SIADS Inc. for NAVAIR indicated that selected modifications of the present WFG would not be cost-effective and would not significantly increase MTBF. These studies concluded that the replacement of the WFG with a Signal Data Converter (SDC) was the preferable solution. The SDC constitutes the state-of-the-art design utilizing components with demonstrated reliability to reduce the parts count, module count, power consumption, and life cycle costs.

The SDC reduces the weight of the modified AV-8A HUD set by four pounds and also enhance the resolution of symbology presented on the PDU.

- 1.2 A contract, N00019-77-A-0350, was awarded to SIADS Inc. in April 1978 to improve the reliability and maintainability of the Head-up display set. This contract covered the Signal Data Converter, Figure one, (initially called the Digital Display Converter) the Digital Display Indicator, Figure two (reported on in Vol. 1), and the Display Set Control, Figure three 3 reported on in Vol. 2). The contract also included the modification of two Waveform Generator test sets. This report covers only the work done on the Signal Data Converter and the test sets.
- 1.3 The contract work was essentially finished by December 1979, except for the completion of the R & M testing and certain data items. In February 1980 by amendment WW04-1G, the remaining items under work order WW-04 were transferred to WW-07, and WW-04 was closed out. During 1979 it was decided by the Navy to utilize random vibration instead of sinusoidal vibration for the R & M tests. This was one factor in the above action. The random vibration reliability tests were later run on similar equipment, the Weapons Aiming Computer, with the results applied to the SDC by similarity. Accordingly this report also closes out CDRL items A032, (R & M Test Report), A035 (Failure Summary) and A037 (Failure Reports) outstanding under WW-07 as they pertain to the Signal Data Converter.

- 1.4 The nomenclature for the Signal Data Converter is as follows:

- a) SDC preproduction units fabricated
under the above contract:

CV-3600/AVQ-30(V).

The corresponding SIADS Inc. part number is 10-109-01.

NOTE: SDC units manufactured under a subsequent production contract have the same Navy nomenclature but the SIADS Inc. part number is 10-109-03.

- b) SDC preproduction units, of "a" above, modified for operation with both the Weapon Aiming Computer (WAC) and the Stability Augmentation and Altitude Hold System (SAAHS):

CV-3677/AVQ-30(V).

The corresponding SIADS Inc. part number is 10-109-02.

NOTE: SDC units of this type manufactured under a production contract have the same Navy nomenclature but the SI Inc. part number becomes 10-109-04.

- c) SDC preproduction units, of "a" above, modified for operation with the WAC only:

CV-3697/AVQ-30(V).

The corresponding SIADS Inc. part number is 10-109-05.

NOTE: SDC units of the type manufactured under a production contract have the same Navy nomenclature but the SIADS Inc. part number becomes 10-109-06.

2.0 PURPOSE OF CONTRACT

The purpose of contract N00019-77-A-0350 (work order WW-04), was to improve the reliability and maintainability of the SDC and related equipment. Analysis and test data to date indicates a substantial increase in both reliability and maintainability will be achieved in operational use. See paragraph 6.2 for details.

3.0 EQUIPMENT DESCRIPTION

The SDC is a digital computer used to generate analog signals which drive the deflector coils on the CRT in the Heads-up Display, provides bright-up (CRT control grid) signals, and supplies voltages for the CRT High Voltage Power Supply and the Display Set Control.

Input signals are received from the Weapons Aiming Computer, cockpit controls, and other aircraft equipment.

Displays are controlled by the Display Set Control.

Seven modes of display are provided: V/STOL, Navigation, Weapons "A", Weapons "B", Air-to-Air, Test 1, and Test 2.

The SDC operates from the 400 cycle 3 phase aircraft power and also utilizes 28V DC for off-on control of the SDC and other elements of the HUD set. Total power consumption is about 110 watts, a portion of which is dissipated in the DDI.

The SDC weighs 17 pounds (7.7kg), is 4.88" wide, 7.81" high, and 15" long; designed to the 1/2ATR-short dimensions.

The SDC CV-3600/AVQ-30(V) is form, fit and functionally interchangeable with the Waveform Generator (202 SUE/3 or 202 SUE/5) and operates with the existing IWAC (219 SUE/1). However, the SDC will not drive the combiner servo motor on the pilots display unit. It should also be noted that the SDC models CV-3677/AVQ-30(V) and CV-3697/AVQ-30(V), although form and fit interchangeable, are not functionally interchangeable with the Waveform Generator, since they must be operated in conjunction with the Weapons Aiming Computer (CP-1444/A). There are also some minor changes required in the aircraft wiring when using the later models of the SDC.

A more detailed description of the SDC is provided in contract data item A005, Equipment Specification.

4.0 MODIFICATIONS

The basic design modifications which were incorporated in the SDC as improvements over the Waveform Generator are summarized below:

- a. Use of 16-bit digital words (instead of 12-bit).
- b. Use of high speed bit-slice (AMD 2901) technology.
- c. Minimal use of analog circuits.
- d. Use of latest high reliability components throughout.
- e. Built-in test circuits with four indication means.
- f. Use of memory components providing for up to 12K, 16-bit words.
- g. Phosphor protection circuitry to minimize CRT failures.
- h. Use of "multiwire" boards.
- i. Improved heat dissipation design.
- j. Extensive environmental testing.

- k. Structural software design.
- l. Improved display characters.
- m. Versatility for display changes.
- n. Spare input channels (8).

Most of these modification features are described in previous contract data items, however, a few of the more interesting features are described below.

4.1 Built-in Test Circuits and Software

Once each frame time (24.576 ms), the computer program examines the power supply voltages, tests RAM memory, tests PROM memory, and tests the deflection circuits. A total of eight tests are made. For each test, a separate word in memory is designated to store the count of the failures which are detected. Thus eight "counters" are used. These software counters are decremented by one count if the corresponding test is good, and incremented by one count if not. If the counter is already at zero, it is kept at zero by proper operation. When a BIT failure is sensed, the corresponding counter is incremented by one count for each frame during which the failure occurs, but decremented by one count each frame during which no failure occurs. If the count in any counter reaches "8", a mechanical "flag" is tripped and remains tripped until manually reset by maintenance personnel. This flag is located on the front of the SDC housing. Since aircraft power transients will occasionally cause a flag trip, to minimize false removals a green LED is also provided on the front of the SDC housing. This LED when lit indicates that the SDC is working properly, and can be used as a confidence indicator to override the mechanical flag indication, and allow the SDC to be kept in service, assuming the display on the HUD is normal. The pilot can view at least two separate test patterns using the Test 1 and Test 2 push buttons on the Pilot's Control Panel to verify the proper SDC operation. Another feature available to the pilot is on the display in Test 1, a cumulative count of the number of times, since the unit was turned on, that the BIT counter reached or exceeded a count of 8. Once the BIT counter exceeds 8, the cumulative counter, displayed to the pilot in the form of four decimal digits, will increment one count each frame up to the limit of 9999. This incrementing will continue until the unit is reset by turning it off and back on, or until the fault disappears. This BIT-fail display is presented in the format "BFXXXX" where the X's represent in decimal digits the current cumulative count of the BIT fail frames which exceed the 8-count threshold set up by the software. This display is useful in providing confidence to the pilot that the SDC is operating properly, and provides an early indication of fault conditions due to degradation or incipient failures. This feature was authorized by contract amendment WW041F.

4.2 Phosphor Protection Circuits

In the Waveform Generator, a failure of the deflection circuits would occasionally cause the CRT beam to remain stationary and burn a spot on the CRT phosphor. To prevent this, circuitry is provided in the SDC which generates each frame a full X and Y test deflection on the CRT. Failure to complete this deflection removes the Bright-Up voltage from the CRT, thus turning off the beam current and preventing damage to the CRT.

4.3 Environmental Tests

The environmental test performed are described in contract data item A010. The results and data are included in data item A012. Briefly, the following tests were run:

- | | |
|--------------------------------|---|
| a. Temperature-Altitude | -54°C, 70,000'
+95°C for 16 hours, ambient pr.
+30°C, 50,000', 4 hours
+60°C, 50,000'
+10°C, 70,000', 4 hours
+35°C, 70,000' |
| b. Vibration | 3 hours each axis at 5.0 g rms, random |
| c. Acceleration | 3 g's to 7 g's depending on axis direction |
| d. Shock
Crash Safety Shock | 3,-15g in each direction of each axis
3,-30g in each direction of each axis |
| e. Humidity | 10 cycles from 28°C to 71°C, at 95% R.H. |
| f. Temperature Shock | 3 cycles from +71°C to -54°C, 4 hours each |
| g. Sand and Dust | 6 hours, 23°C, 1750 FPM
16 hours, 63°C 300 FPM
6 hours, 63°C, 1750 FPM |
| h. Salt Fog | 35°C, 5% NaCl fog for 48 hours |

4.4 Display Characters

In the SDC, each character is displayed as a series of vectors, arcs, or lines when under computer control. This enables the characters to be

displayed in the exact size, shape and position desired. In addition, the writing speed is kept constant to maintain a uniform intensity. This combination provides calligraphic characters of excellent definition, intensity and uniformity.

4.5 Display Changes

Since all of the display, both characters and format, is under software control, changes can be made by modifying the software and inserting new PROMS as needed. Frequently, new input signals can be accommodated as well, with little or no change to the SDC hardware, since spare input channels are provided, as well as spare memory and spare program time.

4.6 Mechanical Design

Several aspects of the Mechanical Design of the SDC represent improvements over the Waveform Generator. The case itself is a thin wall investment casting with reinforcing ribs to dissipate heat and minimize weight. The case was computer analyzed for static and dynamic deflection stress levels resonant frequencies, and mounting security. Results of the final stress analysis computer run showed no problem areas. During random vibration testing, however, a resonance of the top cover was noted, which induced unwanted vibration to the boards. This was corrected by applying silicon sponge rubber to the inside of the cover. This also served to secure the top edges of the boards which were otherwise unsupported.

The power supply was designed as an enclosed box replaceable as an SRA unit, to facilitate maintenance and to confine electrical noise.

All SRA's were designed to plug in, with two wedge lock devices on each board used to secure the SRA in place and insure good heat transfer from the board heat sink to the case. The wedge locks were modified to prevent the bottom wedge from falling off in the event the screw should be unscrewed too far. A cam on each top over of each SRA was provided to facilitate removal of the board from the connector.

Heat sinks were bonded to all SRA boards. The main boards use aluminum heat sinks, insulated from the boards by anodizing and by using 0.005" glass beads as a filler in the epoxy bond. The power supply boards use tinned copper heat sinks which are insulated from the boards by a 0.010" sheet of glass-epoxy board cut to the same pattern as the heat sink.

A computer thermal analysis of the SDC was run and reported on in Data Item A014. Based on the analysis, some modifications to the initial design were made to eliminate hot spots. The final design, tested with thermocouples, was shown to be satisfactory. The hottest parts were, as expected, in the power supply. Accordingly, special attention was given to heat dissipation of the power transistors in the power supply. In addition, considerable design and redesign effort was expended on the power supply to minimize

electrical and thermal stresses, improve voltage characteristics, improve electrical stability, and minimize electrical noise.

Considerable difficulty was experienced with the insulators used between the power transistors and the heat sink. It is necessary to electrically insulate the case of the transistor from ground and hence from the heat sink. The insulator must be a good heat conductor and good electrical insulator, which requirements are somewhat antithetical. Tested were beryllium oxide, mica, anodized aluminum, mylar, kapton, and several formulations of insulators made by the Chomerics Company. The Chomerics insulators were finally chosen although they are subject to slight cold flow, causing the mounting screws to become loose, which, when tightened, strain the solder joints on the printed wiring board. It is necessary to solder the transistor in place only after the mounting has been made, allowed to adjust, then retightened.

5.0 R & M Considerations

5.1 Reliability

The calculated MTBF for the SDC is 1,748 hours, as reported in Data Item A030. This compares favorably with the Waveform Generator which has an MTBF of approximately 75 hours. Failures of the SDC subsequent to the burn-in testing which screens out defective components or workmanship, have been due to external causes, with very few failures contributed by component or workmanship defects. Improvements in the power supply and assembly methods will serve to further reduce failures in the production SDC units. Failures in the CRT high voltage circuits in the past have occasionally caused a failure in the Waveform Generator. Such features should be prevented in the SDC since a voltage limiting gas diode has been installed in the DDI. At the time of this report, the five preproduction SDC's have a cumulative on-time of about 3,000 hours, much of this time being accumulated under environmental stress. This amount of operating time has provided enough failure data to reveal any persistent design defects or weak components. Modifications have been made wherever necessary to correct any problems and to help ensure a high MTBF in operational use.

5.2 Maintainability

The maintainability of the SDC has been enhanced by mechanical, electrical, and software design features.

The SDC has a test connector which allows fault isolation to the SRA level without opening up the unit. Each SRA has a test connector or a test set which allows fault isolation of the defective component. Occasionally a temperature sensitive component or an intermittent connection will fail the test process requiring a longer maintenance time.

Each board has components on one side only to facilitate replacement of parts. Each board is readily removed and replaced. Boards are interchangeable, allowing substitution, if necessary, for testing.

The BIT circuit and indicators help prevent false removals, as described under 4.1.

6.0 Tests and Analyses

- 6.1 Tests performed on the SDC are detailed in Data Item A010. Briefly, the tests include bench performance, burn-in, environmental, reliability, EMI, and power characteristics. All of the preproduction units passed the performance and burn-in tests. Only one unit was subjected to the environmental tests, and after completion the unit was completely refurbished to put it into flightworthy status. One unit underwent EMI testing and another the power measurements.

Test results and data are given in Data Item A012. The SDC passed the environmental tests, but only after an unusual resonance in one board was corrected by increasing the area of the heat sink to act as a stiffener. This change was necessary to prevent fracture of pins on one of the chips mounted near the top of this board.

The SDC passed all EMI tests except for portions of tests CE-04 and CE-03. The EMI results are described in detail in data item A019. In addition to the laboratory EMI tests, additional EMI testing was done at the Naval Air Test Center, Patuxent River, MD, with the SDC installed and operating in the airplane.

6.2 Reliability Development Tests

The contract called for reliability and maintainability testing to confirm and improve the R & M of the SDC. This reliability testing is described in data item A031 (R & M Test Plan Report), and in data item A010 (Test Procedures), Part V, Reliability and Maintainability Tests. The original plan was to run 4,000 hours of tests with temperature cycling and sinusoidal vibration. Just as the testing started, it was decided by the Navy to go to random vibration instead of sinusoidal. It was also decided to run the same type of random vibration tests on the Weapon Aiming Computer (WAC) then under development also. During the period of setting up for the random vibration tests, the Navy further decided that since the SDC and WAC were very similar in mechanical design, and board layout, components, and stress levels, there was no need to run tests on both the SDC and WAC. Because the WAC utilized multiwire boards which were more representative of the boards to be used in the production SDC's, it was decided to run the R & M tests on the WAC and apply the test results to the SDC by similarity. Therefore, the actual R & M tests were not run on the SDC.

The R & M tests run and reported on for the WAC are applicable to the SDC and satisfy data items A032 (R & M Test Results Report), A035 (Failure Summary Report), and A037 (Failure Report) for the SDC program. This data, less A035 (Failure Summary), was reported under A00B and A00C of Contract No. N00019-77-A-0350-WW09.

7.0 Summary of Improvements

- 7.1 The weight of the SDC has been reduced by one pound from the weight of the WFG.
- 7.2 The technology used in the design and construction of the SDC offers a vast performance improvement over the technology of the WFG. This also improved the maintainability with regards to availability of repair components which were becoming increasingly difficult to procure for the WFG due to obsolescence of many components.
- 7.3 The SDC incorporates phosphor protection circuitry to minimize CRT failures of the DDI.
- 7.4 Structural software design used in the SDC improves the maintainability, performance and flexibility of the SDC software over the WFG software.
- 7.5 The reliability has been improved from a performance of 75 hours MTBF for the WFG to a predicted level of 1,748 hours for the SDC.

8.0 Conclusions and Recommendations

- 8.1 The SDC portion of the contract has been successfully fulfilled as projected, by performing the modifications and redesign required to improve system reliability and maintainability factors. All testing has been satisfactorily completed and documented.
- 8.2 It is recommended that the five SDC's, Serial Numbers 001, 002, 003, 004 and 005 be kept at the contractor's facility for use in future laboratory and flight tests of the SDC and Weapon Aiming Computer.

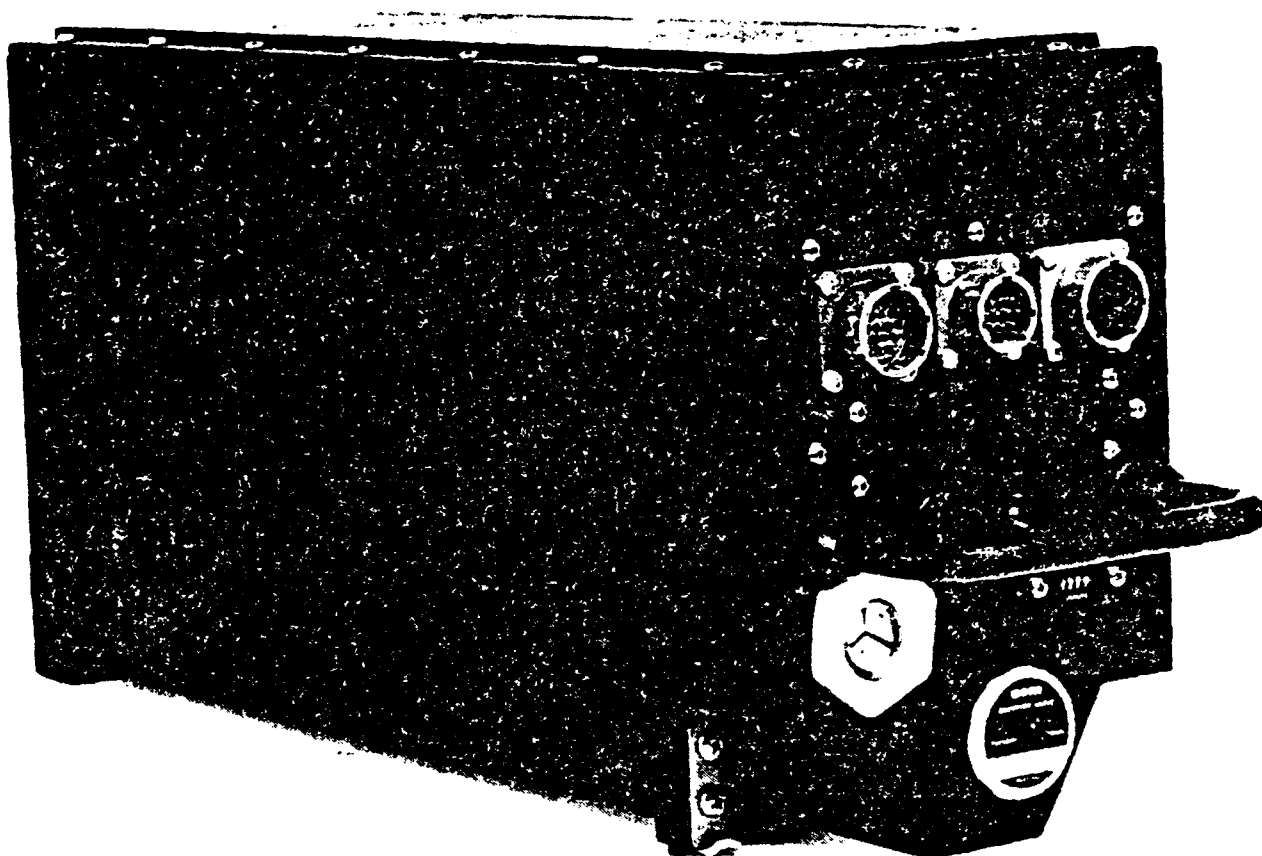


Figure 1. Signal Data Converter

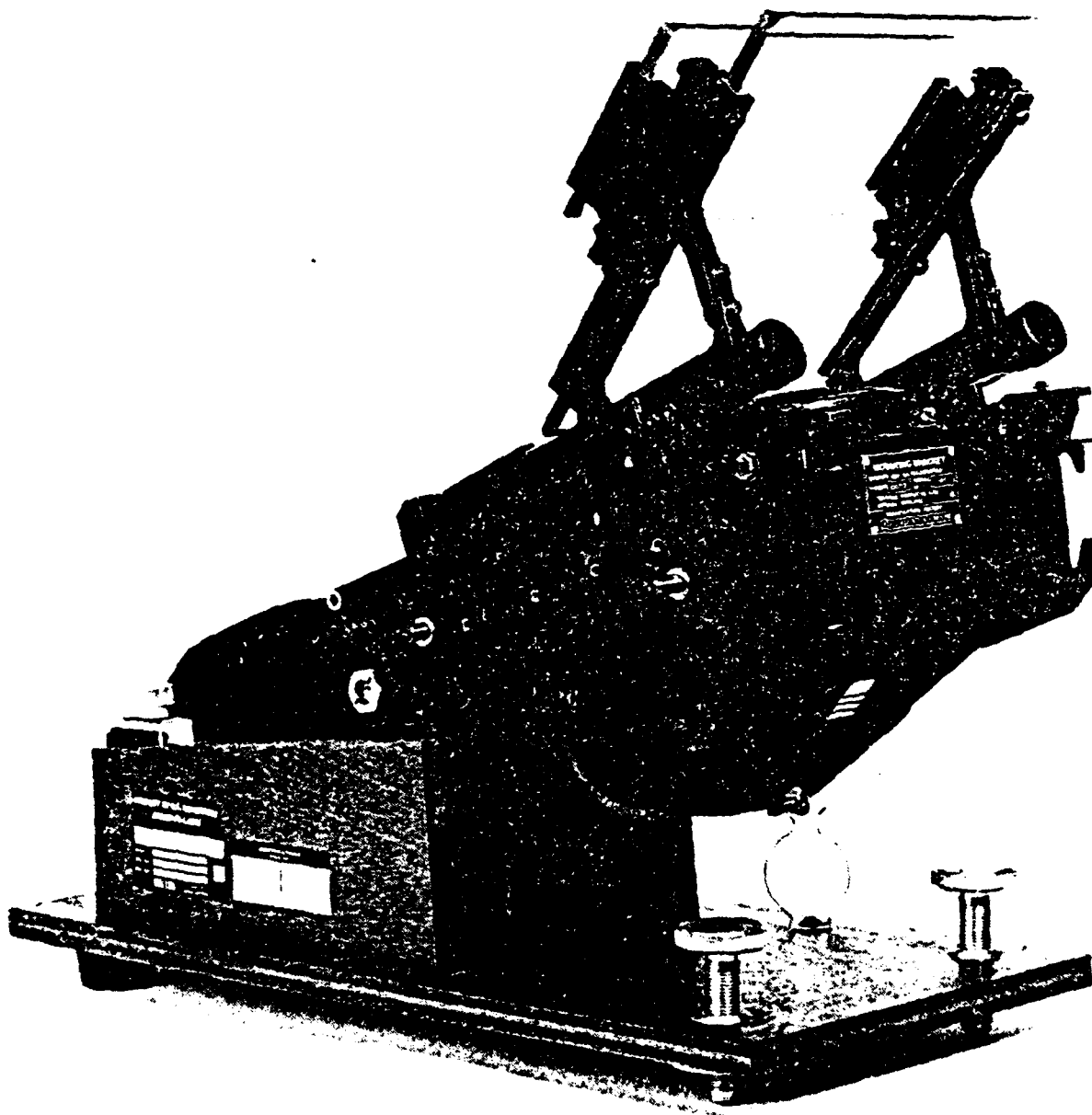


Figure 2. Digital Display Indicator

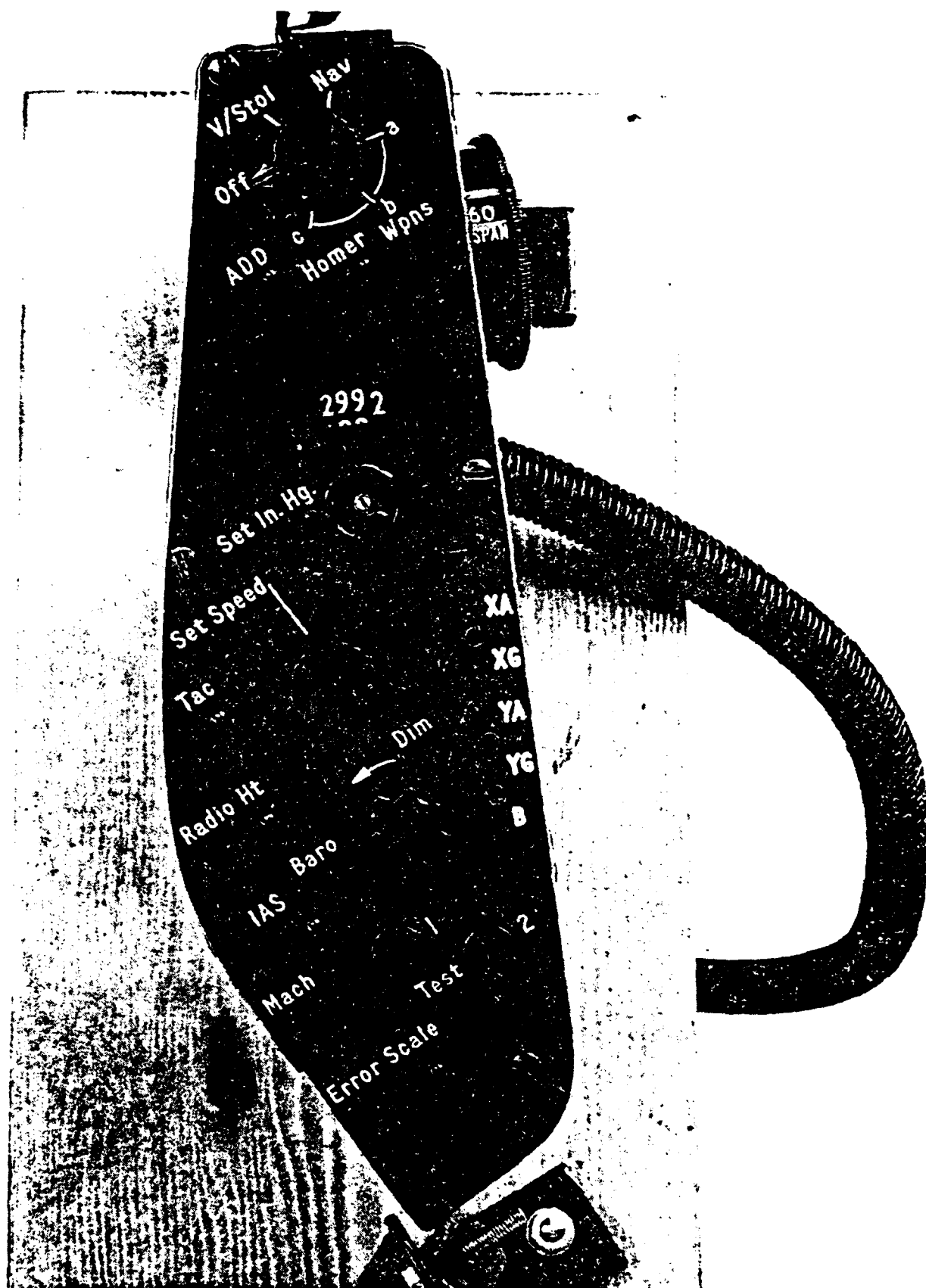


Figure 3. Display Set Control

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